Treatment of Periprosthetic Joint Infection in Total Knee Arthroplasty with a Temporary Intramedullary Nail: Is a Long or Short Nail Better?

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Abstract

To our knowledge, no studies have compared postoperative outcomes between patients who received a temporary short or long intramedullary (IM) nail in the setting of infected total knee arthroplasty (TKA). Therefore, the aim of this study was to compare short-term outcomes for patients who underwent long or short IM nail insertion for treatment of periprosthetic knee infection. Specifically, we compared: (1) success rates; (2) patient reported/functional outcomes; and (3) complications between patients implanted with a short or a long IM nail following PJI of the knee. A retrospective chart review was performed for patients who underwent two-stage exchange arthroplasty with a temporary long or short IM nail between November 2010 and June 2018 at our institution ($n = 67$). Continuous and categorical variables were assessed using *t*-test/Mann–Whitney *U* test and chi-squared test, respectively. Logistic regression analyses were conducted to assess the effect of IM nail length on success rate while adjusting for age, sex, body mass index, and race. A total of 36 patients underwent temporary treatment with a long IM nail, while 31 patients received a short IM nail. There were no differences in success rate for reimplanted patients treated with long and short IM nails (odds ratio 0.992; $p = 0.847$). Fewer patients with a long IM nail went on to reimplantation (52.8 vs. 83.9%; $p = 0.007$). There was no difference in satisfaction (7.86 vs. 7.68; $p = 0.515$), pain scores (3.39 vs. 4.45 points; $p = 0.126$), or Knee Society score outcome scores (150.61 vs. 166.26 points; $p = 0.117$) between long or short IM nail patients. Following reimplantation, there was no difference in the number of patients who became reinfected (15.8 vs. 11.5%; $p = 0.679$) or went on to amputation (0 vs. 7.7%; $p = 0.210$). Periprosthetic joint infection (PJI) is a rare but

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serious postoperative complication following TKA. Our findings suggest that the use of long and short IM nails during two-stage exchange can have equal utility in PJI patients with severe bone defects.

Periprosthetic joint infection (PJI) after total knee arthroplasty (TKA) is an uncommon but severe complication associated with poor patient outcomes and high expenditures. Although less than 3% of primary TKA patients may develop an infection, up to 23% of revision TKAs are complicated by a subsequent infection.[1–4] The preferred method of treatment for PJI, two-stage exchange revision arthroplasty, has a success rate of up to 95%.[5–7] However, its success decreases with each subsequent revision patients undergo, as multiple revisions can lead to significant bone loss and compromised host status.[5,8–10] Undergoing revision with traditional antibiotic spacers has proven reliable with adequate eradication rates and functional outcomes, but spacer utilization can lead to bone loss and increased risk of spacer displacement.[11–17] Therefore, other stabilization and infection eradication techniques have been explored in this cohort of patients.

As a form of static immobilization, intramedullary (IM) nailing have been utilized as an alternative to conventional spacers during two-stage revision. This technique can deliver antibiotics locally and offer sufficient knee stability for patients with preexisting bone loss to allow immediate postoperative ambulation.[18,19] In the setting of infected TKA, IM nails have demonstrated appropriate efficacy, particularly in patients with extensive bone loss.[20–22] Specifically, Waldman et al demonstrated that 100% of TKA patients with PJI became infection free after treatment with an IM nail.[20] Similarly, Mohamed et al reported a 74.2% successful treatment rate in repeatedly revised patients with bone loss implanted with a temporary short IM nail.[22] Others have reported positive outcomes with infection-free success rates ranging from 86.5 to 92%.[21,23,24] Despite the evidence supporting temporary IM nailing for PJI following TKA, the type of nail that can provide optimal outcomes has not been well defined.

Our institution has utilized both short and long IM nails to treat repeat PJI patients with Anderson Orthopaedic Research Institute (AORI) Type II or III bone loss. To date, no studies have compared the postoperative outcomes of these nails when used in this population to treat PJI during a two-stage revision. Therefore, the aim of this study was to compare short-term postoperative outcomes for patients who underwent temporary long or short IM nail insertion for treatment of PJI. Specifically, we compared: (1) success rates; (2) patient reported and functional outcomes; and (3) complications between patients implanted with a short or a long IM nail following PJI of the knee.

Materials and Methods

Patient Selection

A retrospective chart review was performed for all patients with repeat periprosthetic knee infections at our institution. All patients with Type II or III bone defects, as classified according to the AORI system,[25] who underwent two-stage exchange arthroplasty with a temporary long or short IM nail between March 1, 2010, and June 30, 2018, were included for analysis. Patients with AORI Type 0 or I bone defects, PJI treated with antibiotic suppression, debridement with prosthesis retention, and resection arthroplasty were excluded. Patients with prior operations were not excluded. Demographic factors such as age, sex, body mass index (BMI), race, and health status, were collected for all patients. Our institutional review board determined this project exempt from review as it did not meet the criteria for human subjects research.

A total of 389 patients with an infected TKA were identified between 2009 and 2015. Of this total, 167 patients were treated with antibiotic suppression, irrigation and debridement (I&D), or resection arthroplasty. Of the resulting 222 patients, 155 had no preexisting bone loss and underwent two-stage exchange with articulating or nonarticulating spacers. Thus, a total of 67 patients, 31 men and 36 women, were included, 36 long IM nail patients and 31 short IM nail patients. The patients included in the short nail cohort are part of a previously published study.[22] There were no significant differences in mean ages (63 vs. 62 years; $p = 0.746$), sex (55.6 vs. 44.4% females; $p = 0.193$), race (55.6 vs. 61.3% whites; $p = 0.635$), or mean follow-up (25.4 vs. 26.0 months; $p = 0.486$) between the long and short IM nail cohorts. Mean BMI was the only patient demographic that significantly differed between the long and short IM nail groups (39.8 vs. 31.8 kg/m^2; $p < 0.001$) (►**Table 1**). Regarding health status, we found no difference in mean serum albumin levels (2.9 vs. 3.1; $p = 0.283$) or McPherson et al's systemic host grade ($p = 0.821$) between the long and short IM nail cohorts (►**Table 2**). Additionally, there was no difference in the organism cultured at initial IM nail placement ($p = 0.105$) (►**Table 3**).

Management Technique

Surgery consisted of removal of the infected prostheses, I&D, and IM nail insertion. The IM nails were selected based on surgeon preference and were coated with antibiotic cement. The cement was composed of liquid monomer, 3.6 g of tobramycin, and 1 g of vancomycin per every 40-g package of cement prior to insertion. Tobramycin antibiotic powder (4.6 g) alone was used if a patient had an allergy to vancomycin. All patients received standardized institutional postoperative care and were instructed to weight-bear as tolerated immediately. Parenteral antibiotics were prescribed for at least 6 weeks under the guidance of blood and aspirate cultures as well as microbiome sensitivities. Antibiotics were prolonged in cases where infection was not eradicated. Serum infection markers, such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), were assessed throughout the course of antibiotic therapy.

Table 1 Descriptive analysis demonstrating patient demographics

	Long intramedullary nail	Short intramedullary nail	*p*-Value
Number of patients	36	31	
Age[a] (y)	63.4 (9.8)	62.4 (13.8)	0.746
BMI[a] (kg/m^2)	39.8 (8.1)	31.8 (7.0)	<0.001
Length of stay[a] (d)	7.4 (7.8)	5.8 (3.2)	0.278
Female	20 (55.6%)	16 (44.4%)	0.193
Race			
White	20 (55.6%)	19 (61.3%)	0.635
African American	16 (44.4%)	12 (38.7%)	

Abbreviation: BMI, body mass index.
[a]Values are reported as mean and standard deviation in parentheses.

Table 2 Host factors

	Long intramedullary nail	Short intramedullary nail	*p*-Value
Albumin[a]	2.9 (0.6)	3.1 (0.7)	0.283
McPherson et al's systemic host grade			
A	3 (8.3%)	4 (12.9%)	0.821
B	25 (69.4%)	20 (64.5%)	
C	8 (22.2%)	7 (22.6%)	

[a]Reported as mean and standard deviation in parentheses.

In cases where the CRP and ESR levels were questionable, joint aspiration was performed to rule out ongoing infection. Once patients were considered to have cleared the infection by improvement in symptoms, downward trending in CRP and ESR levels, or a negative aspiration, they were scheduled for reimplantation. Patients were reimplanted if intraoperative pathology reported negative frozen sections.

Table 3 Organism cultured at initial intramedullary nail placement

	Long intramedullary nail	Short intramedullary nail	*p*-Value
Periprosthetic knee infections (*N*)	36	31	0.105
No growth	15 (41.7%)	13 (41.9%)	
Methicillin-resistant *Staphylococcus aureus*	4 (11.1%)	4 (12.9%)	
Enterococcus group D	2 (5.6%)	1 (3.2%)	
Vancomycin-resistant enterococci group D	1 (2.8%)	1 (3.2%)	
Pseudomonas aeruginosa	2 (5.6%)	0 (0%)	
Staphylococcus aureus	4 (11.1%)	0 (0%)	
Coagulase-negative staphylococci	4 (11.1%)	8 (25.8%)	
Streptococcus anginosus	1 (2.8%)	0 (0%)	
Streptococcus viridians	1 (2.8%)	0 (0%)	
Candida albicans	0 (0%)	1 (3.2%)	
Escherichia coli	0 (0%)	1 (3.2%)	
Polymicrobial	1 (2.8%)	2 (6.5%)	
Proteus mirabilis	1 (2.8%)	0 (0%)	

Variables

Health status was graded preoperatively according to patient serum albumin levels and the McPherson et al's classification.[26] The microorganism cultured from intraoperative tissue specimens was collected and compared between the cohorts. Treatment success was determined using the Delphi-based consensus definition of successfully treated PJI: infection eradication, no further surgical intervention for infection after reimplantation, and no PJI-related mortality.[27]

Postoperative complications such as reinfection and amputation were documented. Patient-reported outcomes included pain and satisfaction. Perioperative pain intensity was measured by utilizing patient visual analog scale (VAS) scores. In addition to preoperative baseline scores, VAS scores were collected up to 48 hours postoperatively at 8-hour intervals and reported as area under the curve. Satisfaction was assessed via a postoperative survey, and scored out of 10. Functional outcomes were assessed using VAS and Knee Society scores (KSSs) from the patient's last clinic follow-up visit.

Data Analysis

Continuous and categorical variables were assessed using Student's *t*-test, Mann–Whitney *U* test, and chi-squared test, respectively. Logistic regression analyses were conducted to assess the effect of IM nail length on success rate while adjusting for age, sex, BMI, and race. A *p*-value of 0.05 was set as the threshold for statistical significance. All statistical analysis was performed using SPSS version 25 (IBM Corporation; Armonk, NY).

Results

Success Rate

After adjusting for age, sex, BMI, and race, there was no differences in success rates for reimplanted patients treated with long and short IM nails (odds ratio 0.992; $p = 0.847$) at a mean follow-up of 26.0 months (►**Table 4**). Fewer patients with a long IM nail went on to reimplantation compared with patients with a short IM nail (52.8 vs. 83.9%; $p = 0.007$) (►**Table 5**). In the interchange period, there were no significant differences between long and short IM nail cohorts requiring exchange for a second nail (31.6 vs. 11.5%; $p = 0.137$).

Patient-Reported and Functional Outcomes

There were no differences in pain intensity between the long and short IM nail groups during the 48-hour interval postoperatively (114.61 vs. 134.93 through 0–24 hours; $p = 0.148$ and 128.50 vs. 143.74 points through 24–48 hours; $p = 0.191$) (►**Table 6**). Similarly, there were no differences reported in postoperative satisfaction (7.86 vs. 7.68; $p = 0.515$). There were also no differences in VAS pain scores (3.39 vs. 4.45 points; $p = 0.126$) and KSS functional outcome scores (150.61 vs. 166.26 points; $p = 0.117$) between patients reimplanted with a long or short IM nail at a mean follow-up of 32 months.

Complications

Following reimplantation, there was no difference in the number of patients who became reinfected (15.8 vs. 11.5%;

Table 4 Logistic regression model for treatment success

Variable	Odds ratio	*p*-Value	95% confidence interval
Age	0.997	0.917	0.945–1.053
BMI	0.992	0.847	0.915–1.076
Race			
Black or African American	–	Reference	–
White	3.354	0.033	1.101–10.223
Sex			
Female	–	Reference	–
Male	1.472	0.499	0.480–4.510
Host immune status			
A	–	Reference	–
B	1.234	0.827	0.189–8.071
C	0.907	0.934	0.90–9.156
Albumin	1.206	0.724	0.427–3.402
Required nail exchange	0.512	0.422	0.100–2.619
IM nail length			
Long	–	Reference	–
Short	0.992	0.847	0.915–1.076

Abbreviations: BMI, body mass index; IM, intramedullary.

Table 5 Outcomes and complications for temporary long and short intramedullary nails

	Long intramedullary nail	Short intramedullary nail	*p*-Value
Number of periprosthetic knee infections (*N*)	36	31	
Outcome measure			
Follow-up for all[a] (mo)	31.5 (24.0–226.0)	32.0 (24.2–85.0)	0.806
Duration of antibiotics[a] (d) (SD)	42.0 (35–42)	42.0 (14–56)	0.457
LOS[b] (d)	7.42 (7.8)	5.77 (3.2)	0.278
Reimplantation			
Reimplanted	19 (52.8%)	26 (83.9%)	0.007
Time until reimplant[a] (mo)	10.3 (4.0–41.0)	2.7 (0.1–16)	0.008
Treatment success	16 (84.2%)	19 (73.1%)	0.481
Interchange period			
Required a second intramedullary nail[c]	6 (31.6%)	3 (11.5%)	0.137
Complications following reimplantation			
Infection[c]	3 (15.8%)	3 (11.5%)	0.679
Amputation[c]	0 (0%)	2 (7.7%)	0.210
Retention of nail			
Retention of nail[c]	17 (47.2%)	5 (16.1%)	0.007
Treatment success[c]	16 (94.1%)	4 (80.0%)	0.334
Complications with retention of nail			
Infection[c]	1 (5.9%)	0 (0%)	0.999
Amputation[c]	1 (5.9%)	0 (0%)	0.999
Irrigation and debridement[c]	0 (0%)	1 (20.0%)	0.999

Abbreviations: LOS, length of stay; SD, standard deviation.
[a]Median (range).
[b]The values are given as the mean and range in parentheses.
[c]The values are given as the number of cases with the percentage in parentheses. The percentages were determined from the total number of cases that retained the intramedullary nail and cases that went on to reimplantation.

Table 6 Patient-reported outcomes and functional scores for patients treated with temporary long or short intramedullary nails

	Long intramedullary nail	Short intramedullary nail	*p*-Value
Pain intensity			
Pain intensity (AUC) 0–24 h	114.61 (44)	134.93 (65.13)	0.148
Pain intensity (AUC) 24–48 h	128.50 (38.21)	143.74 (53.37)	0.191
Patient-reported satisfaction (out of 10)			
Satisfaction	7.86 (1.15)	7.68 (1.13)	0.515
Functional and PRO scores at last follow-up for patients who retained the IM nail			
KSS	117.61 (27.91)	103.52 (23.41)	0.198
VAS	4.52 (2.63)	5.29 (3.16)	0.154
Satisfaction	7.65 (1.11)	7.33 (1.03)	0.553
Functional and PRO scores at last follow-up for reimplanted patients			
KSS	150.61 (45.01)	166.26 (33.72)	0.117
VAS	3.39 (2.23)	4.45 (3.19)	0.126
Satisfaction	8.05 (1.18)	7.76 (1.16)	0.416

Abbreviations: AUC, area under the curve; IM, intramedullary; KSS, Knee Society score; PRO, patient-reported outcomes; VAS, visual analog scale.
Note: The values are given as the mean and standard deviation in parentheses.

$p = 0.679$) or went on to amputation (0 vs. 7.7%; $p = 0.210$) (►**Table 5**).

Discussion

PJI following TKA is a serious complication associated with increased patient morbidity and mortality. Temporary IM nail utilization in combination with two-stage exchange arthroplasty is an option in the treatment of PJI when severe bone loss is present, as the nail offers sufficient knee stability for immediate mobilization.[18,22] Following infection eradication and explantation of the nail, patient function can potentially be restored, and activity levels may improve. Both long and short IM nails have been successful in two-stage exchange, but their outcomes have not been previously compared. Therefore, this study compared short-term postoperative outcomes for patients who underwent long or short IM nail insertion for treatment of PJI during two-stage exchange arthroplasty. Our findings demonstrated fewer long nail patients underwent reimplantation, retaining their nail after surgery. We also found that there were no statistical differences in reinfection, amputation, or successful infection eradication rates between the cohorts. Additionally, no differences in patient-reported or functional outcomes were noted between the cohorts. The utilization of both long and short IM nails during a two-stage revision TKA are comparable in patients with prior bone loss.

This study is not without limitations. We found a difference in BMI between the long and short IM nail cohorts. Long IM nails are implanted in patients with larger stature due to surgeon preference, and therefore, it would be expected to see a higher BMI in this group. Nevertheless, this difference did not affect the statistical analysis as this variable was adjusted for in the logistic regression analysis. Furthermore, as the incidence of PJI is as low as 0.7 to 2%,[28] a large number of study patients are necessary to detect significant differences between cohorts. Although this study is likely underpowered to detect this difference, a comparison between long and short IM nails has not been explored, and is therefore valuable, particularly because differing implants can achieve temporary fixation during PJI treatment. Furthermore, post hoc power analysis with study parameters of 80% power and an $\alpha = 0.05$ revealed the need for 68 total patients, which is in line with our study.

Our study found that fewer patients with a long IM nail went on to reimplantation. Per chart review, patients felt satisfied that they had adequate stability and pain control and were reluctant to undergo further surgical intervention. These patients were in effect, successfully managed with a one-stage exchange. Of those who underwent reimplantation, we found varied success rates for infection eradication between the long and short nail cohorts. Similarly, studies regarding nonarticulating cement spacers, which are comparable to IM nails, report wide-ranging infection eradication rates. Fehring et al performed a retrospective study on 25 PJI patients treated with a static cement spacer and found 22 patients (88%) were free of infection at a mean follow-up of 36 months.[16] The authors reported unexpected bone loss in 15 (60%) of the 25 patients, a complication commonly associated with the use of these spacers.[4,13] In another retrospective review of failed infected TKAs, Johnson et al reported a success rate of 83% (28 of 34 patients) in their cohort treated with nonarticulating cement spacers.[12] Conversely, Choi et al performed a retrospective study on 33 PJI patients treated with static cement spacers and found 22 patients (67%) were infection free at 58 months of follow-up.[29] These studies demonstrate the variability of infection eradication with traditional static spacers, which help corroborate the eradication rates of the IM nails utilized as nontraditional spacers in this study.

We found no differences in postoperative pain intensity or KSSs between the groups at a mean 2-year follow-up. Several studies have shown that functional outcome also improved when patients treated with static spacers undergo reimplantation. Lichstein et al performed a retrospective case series on 107 infected TKA patients and found that KSS knee scores improved from a preoperative median of 36 (range: 24–48) to a postoperative median of 86 (range: 22–45).[30] They also found that KSS function scores increased from a median of 32 (range: 22–45) to a postoperative median of 85 (range: 61–97). Fehring et al utilized the Hospital for Special Surgery rating to evaluate functional outcomes and found that patients treated with a static spacer block ($n = 25$) had an improved mean score of 83 points (range: 37–98).[16] Our study expands on these previous studies by including a pain intensity analysis, which these studies fail to include.

Our findings demonstrated no difference in the number of patients who became reinfected or went on to amputation. In the cohort of previously published short nail patients, Mohamed et al reported the observed overall success rate of 74.1%, with a reinfection rate of 11.5% and no amputations.[22] Other studies report similar reinfection rates and subsequent surgical management. A retrospective review by Emerson et al studied postoperative outcomes for 26 patients treated with a static block spacer for infected TKAs.[17] The authors reported a reinfection rate of 7.6% at 36 months that increased to 23% (6 of 26) after an average of 7.5 years. In a retrospective study of 38 patients implanted with static spacers, Freeman et al reported three reoperations (7.8%) in the group of patients who remained infected or became reinfected.[31] In another retrospective study evaluating outcomes for cement spacers ($n = 10$), Jämsen et al reported that one patient underwent an above-the-knee amputation due to a life-threatening infection.[32] Despite the small sample sizes reported, results from these studies coincide with our findings, reporting low reinfection and amputation rates. Our comparative study demonstrates similar outcomes between IM nails and static spacers, suggesting they have a place in the treatment of infected TKA during two-stage exchange arthroplasty. A long IM nail offers the potential for a one-stage revision, while a short IM nail offers increased mobilization during the interim of a two-stage exchange. This information can provide surgeons with more tools to assist their more complex patients.

Conclusion

Temporary IM nail placement can be an effective alternative technique to traditional antibiotic spacers for PJI patients with considerable bone loss. This study compared long and short IM nails in this population of patients, and found a subset of patients implanted with a long IM nail were successfully treated with one-stage exchange. We also found no difference in success rates for infection eradication for reimplanted patients treated with a long or short IM nail at short-term follow-up. These data suggest that the use of long and short IM nails during two-stage exchange can have equal utility in PJI patients with severe bone defects.

Note

Institutional Review Board has determined this project exempt from review as this does not meet the criteria for human subjects research.

Conflict of Interest

J.D.C. reports personal fees from Biocomposities, personal fees from Bonesupport, personal fees from DePuy Synthes, personal fees from MHE Coalition, personal fees from Orthofix, Inc, personal fees from OrthoPediatrics, personal fees from Pega Medical, personal fees from Smith and Nephew, personal fees from Stryker, personal fees from University of Florida, personal fees from Zimmer, personal fees from Zimmer Biomet, outside the submitted work. R. E.D. reports other from Flexion Therapeutics, other from Orthofix Inc, other from Stryker Corp, other from United Orthopedics Corp, other from Tissue Gene, outside the submitted work. R.E.D. reports other from Flexion Therapeutics, other from Orthofix Inc, other from Stryker Corp, other from United Orthopedics Corp, other from Tissue Gene, outside the submitted work. F.J.P. reports other from Biocomposites Inc., personal fees from Total Joint Orthopedics, personal fees and other from VisualDx, outside the submitted work.

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